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Using IEC TC57 CIM Standards to Integrate Asset Health Information

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SUMMARY

Work done in the EPRI Smart Grid Substation Lab in 2011 demonstrated the use of International Electrotechnical Committee (IEC) Common Information Model (CIM) standards in creating an integration environment to provide transformer health information to the control center. As expected, the actual deployment of a prototype solution utilizing standards both validated the quality of the standards and provided the opportunity for learning.

In the project, the scope of transformer-related CIM data exchange was expanded beyond what historically has been done to include asset health measurement information and routine test results. The implemented information exchange leveraged the new CIM v15 to address the required spanning of the balanced transmission view of a transformer and the unbalanced distribution view. Extensions were made to the CIM model to support the exchanging test procedure results for the transformer assets (tanks).

Modeling and instantiation assumptions were made by the project and knowledge was gained that may be helpful to the CIM standards organizations in defining and refining standard CIM profiles.

KEYWORDS

Common Information Model
IEC 61970
IEC 61968
CIM 15
Transformer Health
Information Exchange

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Introduction

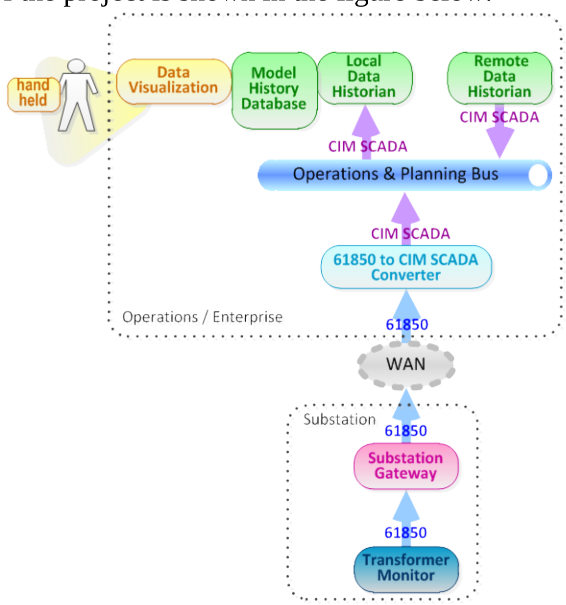
Prototype deployments are often an essential step in making progress toward standards adoption. Such deployments exercise features of a standard, validate its design, expose areas requiring better definition and illustrate a standard's value. A project implemented in EPRI's Smart Grid Substation Lab in 2011 served as a prototype deployment that validated and proposed refinements to the new transformer model in version 15 of the Common Information Model (CIM) standards.

The project created an integration environment to support the exchange of transformer health-related measurement information and maintenance test results. The project leveraged the CIM v15 transformer model heavily as it expanded the scope of transformer-related data exchange beyond the more typical areas of network model or asset information.

The implemented information exchange required a number of design decisions and modeling assumptions, including spanning the balanced transmission application view of a transformer and the unbalanced distribution application view, leveraging the Terminal class in a new way and defining a model-based strategy for measurement identification and naming. It also required extending the Common package of the 61968 CIM standard to include the modeling of test procedure results for the transformer assets (tanks).

Project Architecture

The high-level architecture of the project is shown in the figure below.



Real-time measurement data was continuously provided to an Operations & Planning Bus by two sources: the Remote Data Historian and the Transformer Monitor (via a Substation Gateway and a 61850 to CIM SCADA Converter). The Transformer Monitor was supplemented with an input signal generation device which produced 61850 messages containing information relevant to transformer health. Measurement data was consumed in real-time by the Local Data Historian and displayed to the operator by a Data Visualization tool. The Data Visualization tool utilized a CIM-based data model in the Model History Database to access the historic measurement data in the Local Data Historian. The Model History Database also contained historic Dissolved Gas Analysis (DGA) sample test data in CIM format.

Sample Transformers

The project utilized utility-provided information on 10 transformers in addition to the information coming from the Transformer Monitor. All transformers for which utility information was provided were transmission transformers. Some were two-winding, some three-winding. Some transformers were actually transformer banks comprised of three single-phase tanks, other transformers had all three phases contained in one tank. Different transformers had different numbers of measurements associated with them and the measurements came from a variety of locations on the transformers. DGA sample test data was provided for four transformers, with two sets of the test data being associated with the individual tanks of three-tank transformer banks and two sets of test data coming from single tank transformers.

Project Data Exchange

All information being exchanged in the project related to transformers: some was network- and equipment-related, some was measurement-related, some was asset-related and some was sample test results-related. With the exception of 61850 format data moving from the Transformer Monitor to the 61850 to CIM SCADA Converter, all information exchanged in the project solution was structured according to the CIM model.

In the prototype deployment, the exchanged data was sourced from the following applications and devices:

- Current measurement data –Transformer Monitor and Remote Data Historian
- Historic measurement data – Local Data Historian
- Network and equipment information – Model History Database
- DGA sample test results information – Model History Database

The last two types listed above, sourced by the Model History Database, were accessed by the Data Visualization tool and afforded opportunities for exploring interface definitions using the CIM v15 transformer model.

CIM Transformer Information Exchange Precedents

Three International Electrotechnical Commission (IEC) standards (61970, 61968 and 62325) collectively provide the description of the CIM. Historically, the use of the CIM to support the exchange of transformer-related information has been most heavily focused in the areas of network connectivity and equipment electrical characteristics, information which is needed by power flow applications. This information has traditionally been done separately for transmission applications (which view transformers as operating in a balanced condition) and distribution applications (where the load is modeled individually for each phase). The current CIM profiles supporting these exchanges reflect that separation: the Common Power System Model (CPSM) profiles describe balanced model exchanges and the Common Distribution Power System Model (CDPSM) profiles describe unbalanced model exchanges.

Additionally, there has been work done in the exchange of transformer asset information via the messaging profiles specified in Part 4 of the 61968 standard, which supports the exchange of asset information but not DGA sample test result information.

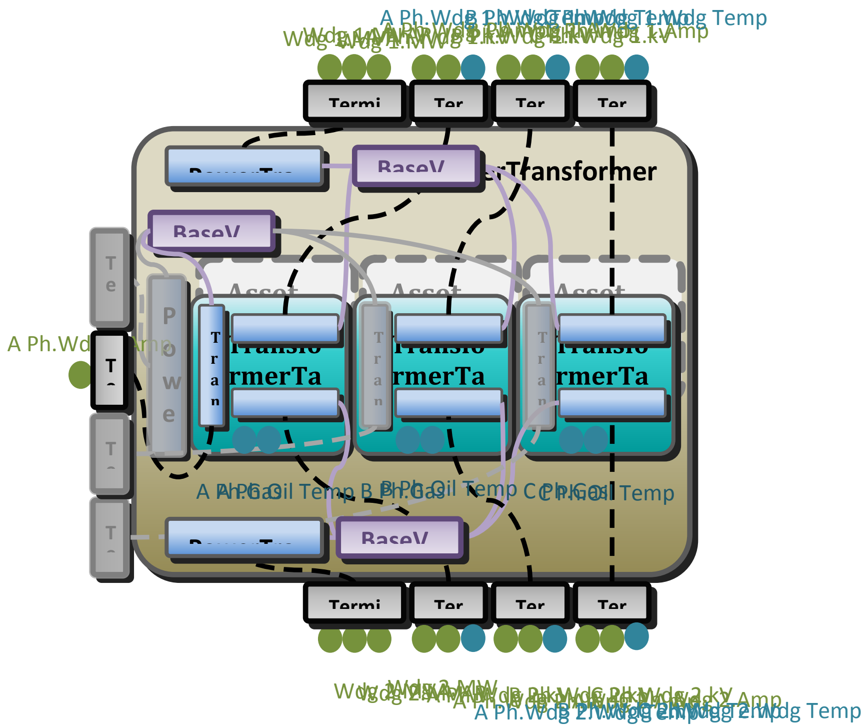
CIM Version 15

Version 15 of the CIM (CIM v15) included a significant number of model improvements. Major among them were modifications to the transformer model to support both balanced and unbalanced modeling, to more accurately reflect the relationship between a transformer and its terminals and to support the relationship of certain test results to an Asset as opposed to electrical system Equipment.

Instance Modeling for the Transformer Measurement and Asset Profile

Instance diagrams and instance models were used to analyze the modeling requirements of the first type of information provided by the Model History Database and consumed by the Visualization tool: the equipment information, including associations to measurement data and assets.

The generalized instance drawing (next page) illustrates the class instances and relationships required to support the profile for transformer equipment and associations to measurement and asset data utilized by the project.



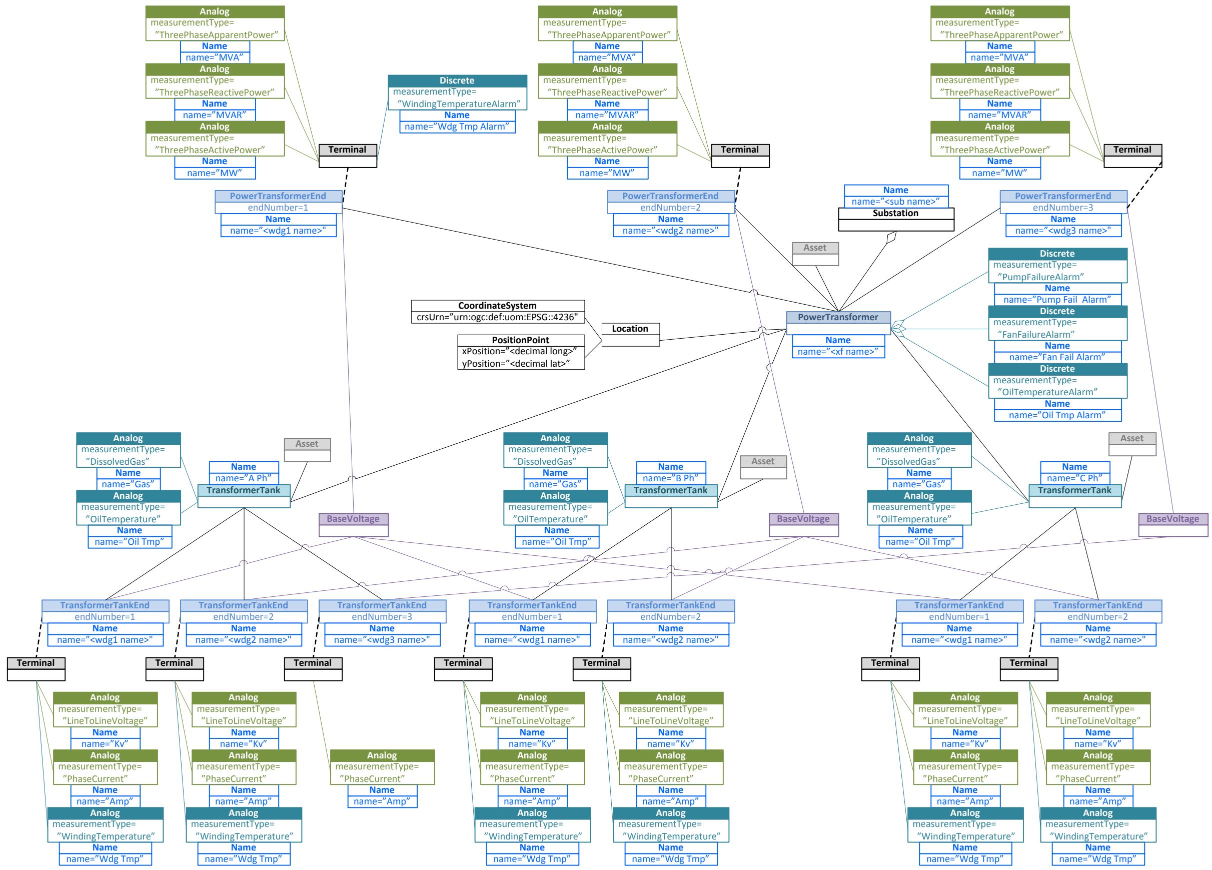
Measurements are represented by solid circles with an M in the middle. Generalized Measurement names are shown with electrical system-related Measurements in green and asset health-related Measurements in teal. The two possible variations of transformer-to-asset association are shown: PowerTransformer to Asset and TransformerTank to Asset. Instances not needed for the project, but which are part of a complete transformer model, are present but grayed out.

The following instance modeling assumptions necessary for the profile for transformer equipment and associations to measurement and asset were identified and explored based on CIM v15:

- Asset instances corresponded directly to physical transformer tanks. The relationship from the Asset to the equipment was defined as an association between an Asset instance and a PowerTransformer instance for the single-tank transformers and as three Asset instance to TransformerTank instance associations for the three-tank transformer banks.
- A single transformer model can simultaneously include instances of both the classes used for balanced modeling and those needed for unbalanced modeling. The project need to support the precise location of Measurement relationships to parts of a transformer led to this conclusion.
- In the project, four instances of Terminal class were necessary for each winding:
  - one reflective of the balanced model, with a phases attribute value of ABC
  - three that are phase-specific reflecting the unbalanced view which have phases attribute values of A, B and C respectively

  This modeling deviates from what has previously been documented as “normal” transformer modeling, but given the nature of the Measurement instances present in the, the decision was made to model four Terminal instances for each transformer winding.
- Measurement instances cannot be associated with PowerTransformerEnd or TransformerTankEnd instances, because the latter are specializations of IdentifiedObject instead of PowerSystemResource. While the project respected this standard CIM model limitation, it is observed that allowing such associations would provide improved clarity for non-electrical Measurements.

An instance model (next page), was used to define the requirements for a project Transformer Measurement and Asset profile to support the exchange of transformer equipment-related information used for asset health. While the defined profile fully supports the identification of the transformer-related MeasurementValues and transformer-related Assets, it does not support the exchange of either MeasurementValue instances or Asset-related information.

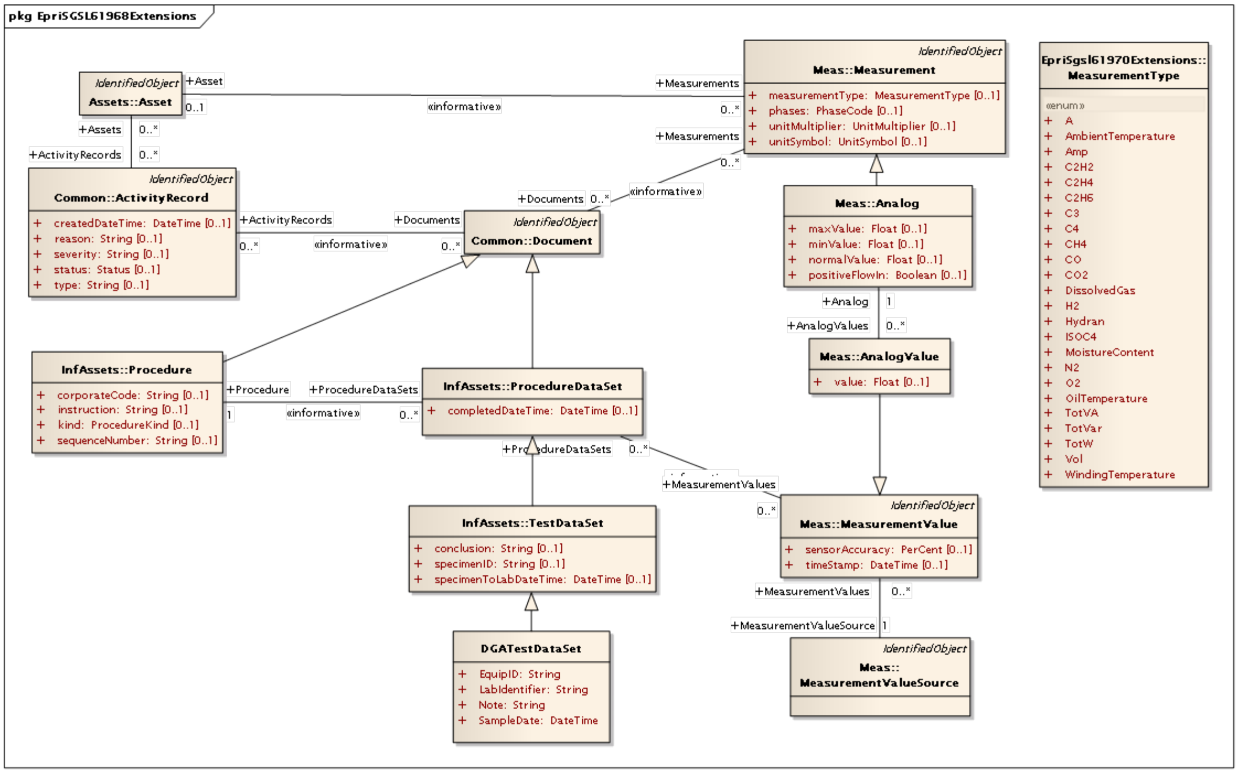


The project Transformer Measurement and Asset profile bears a significant resemblance to the Equipment profile the CPSM (IEC 61970-452) standard and to the Functional profile of the CDPSM (IEC TC 61968-13) standard, spanning both standard profiles due to its need for both balanced and unbalanced transformer modeling. It seems very likely that the need for simultaneous balanced and unbalanced transformer models is one that will present itself with increasing frequency. In the future, unbalanced modeling will be utilized more by Transmission applications, particularly with the advent of widely-deployed synchrophasors. Additionally, continuous network models spanning the transmission and distribution systems will become essential to applications addressing the grid impacts of distributed generation and widespread demand response.

Model Extension for DGA Sample Test data and its Association to Assets

The existing CIM model for asset-related information was used as a basis for the organization of DGA sample test data. The class diagram (next page) illustrates the classes and relationships required to support the transformer asset DGA sample test results data utilized by the project.

The only new classes defined for this project were DGATestDataSet and MeasurementType data type. DGATestDataSet is a specialization of TestDataSet which was needed to add new attributes for equipment ID from which the samples were taken, ID of lab performing the tests, date/time the sample data was collected and freehand notes. MeasurementType data type replaces String data type for measurementType to provide enumerations for each type of DGA test data. Otherwise the rest of the model shown is taken unaltered from the 61968-11 CIM standard.



Conclusions

In the project, the scope of transformer-related CIM data exchange was expanded beyond what historically has been done to include asset health measurement information and routine test results. The implemented information exchange leveraged the new CIM v15, which provided a very solid basis for structuring the information required by asset health application data exchange. It supported clear, model-based organization of transformer, measurement and asset data which would have been impossible using the previous CIM transformer model. A number of design decisions and modeling assumptions were made, including spanning the balanced transmission application view of a transformer and the unbalanced distribution application view, leveraging the Terminal class in a new way and defining a model-based strategy for measurement identification and naming. It also required extending the Common package of the 61968 CIM standard to include the modeling of test procedure results for the transformer assets (tanks).

The knowledge gained, the assumptions made and the questions and possibilities raised by the CIM v15 transformer modeling done by the project are being made available to both IEC TC57 Working Group 13, which is responsible for the 61970 standard, and Working Group 14, which is responsible for the 61968 standard. The work of the project will hopefully have value for utilities and vendors alike as each Working Group considers the modeling assumptions made on the project and updates its network model exchange profile document to reflect the new features of CIM v15.

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